Geostationary Operational Environmental Satellite (GOES)

GOES-R Series

Advanced Baseline Imager

Performance and Operational Requirements Document (PORD)

Implementation Review

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National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

To verify the correct version of this document, please contact the GOES R Series Requirements Management Office on 301-286-7898

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1 Scope

1.1 Identification

This Performance and Operational Requirements Document (PORD) sets forth the performance requirements for the National Oceanic and Atmospheric Administration (NOAA) Advanced Baseline Imager (ABI).

1.2 Mission Review

The ABI is a multi-channel, visible through infrared, passive imaging radiometer used to measure environmental data as part of a 3-axis stabilized, geostationary weather satellite system. The ABI, in conjunction with a sounding instrument, remotely collects data on the Earth's surface (land and water) and atmosphere to aid in the prediction of weather and climate monitoring. The ABI data provides moderate spatial and spectral resolution at high temporal and radiometric resolution to accurately monitor rapidly changing weather.
The ABI objectives are as follows:

- Provide environmental data that will be used by NOAA and other public and private agencies to produce routine meteorological analyses and forecasts.

- Maintain continuity of Geostationary Operational Environmental Satellite (GOES) services to the user agencies.

- Provide environmental data that will be used to expand knowledge of mesoscale and synoptic scale storm development and provide data that may be used to help in forecasting severe weather events.

- Provide data that will be used the ABI objectives are as follows:

The ABI instrument, designated as ABI in this document, provides data to the ABI Ground System, designated as ABI-GS in this document, via the spacecraft communication system. The ABI-GS takes the ABI data, spacecraft telemetry data, orbit determination data and other required information and autonomously generates radiometrically calibrated and navigated data for the NOAA users.

The ABI-GS will be procured by the Government but will implement algorithms developed by the ABI contractor to satisfy ABI performance requirements.

The ABI-GS will calibrate and then resample the ABI data to generate the fixed grid output on parallel North-South lines with the pixels on the specified output fixed grid. Resampling requires that the raw imagery be adequately sampled to maintain radiometric accuracy after resampling. The specified ABI performance parameters such as Modulation Transfer Function (MTF), Image Navigation and Registration (INR), etc., will be measured after the resampler.

1.3 Document Overview

This document contains all performance requirements for the ABI instrument. This document, the General Interface Requirements Document (GIRD), and the ABI Unique Instrument Interface Document (UIID) define all instrument to spacecraft interfaces for the ABI instrument.

1.4 Terminology

The term "(TBS)", which means "to be specified", means that the contractor will supply the missing information in the course of the contract. These serve as a placeholder for future requirements. The contractor is not liable for compliance with these "placeholder" requirements, as insufficient information is provided on which to base a design.

The term "(TBR)", which means "to be refined/reviewed", means that the requirement is subject to review for appropriatenessand subject to revision. The contractor is liable for compliance with the requirement as if the "TBR" notation did not exist. The "TBR" merely provides an indication that the value is more likely to change in a future modification than requirements not accompanied by a "TBR".

1.5 Conflicts

ABIPORD8 In the event of conflict between the referenced documents and the contents of this ABI PORD, the contents of the ABI PORD **shall** be the superseding requirements.

ABIPORD9 In the event of a conflict involving the external interface requirements, or in the event of any other unresolved conflict, the NASA contracting officer **shall** determine the order of precedence.

1.6 Requirement Weighting Factors

The requirements stated in this ABI PORD are not of equal importance or weight. The following paragraphs define the weighting factors incorporated in this document.

- **Shall** designates the most important weighting level; that is, mandatory. Any deviations from these contractually imposed mandatory requirements require the approval of the NASA contracting officer.

- Will designates a lower weighting level. These will requirements designate the intent of the Government and are often stated as examples of acceptable designs, items, and practices. Unless required by other contract provisions, noncompliance with the will requirements does not require approval of the NASA contracting officer and does not require documented technical substantiation.

- May designates the lowest weighting level, possibility, or discretion of the Government or contractor.

1.7 Definitions

Throughout this document, the following definitions apply:

<u>Accuracy:</u> Refers to the error in a measurement, that is the difference between the measurement result and the object to be measured (the measured or true value). It includes both systematic and random errors. Systematic errors must be estimated from an analysis of the experimental conditions and techniques. Random errors can be determined, and reduced, through repeated

measurements under identical conditions

Albedo: Refers to the fraction of the solar spectrum taken from the default MODTRAN solar irradiance file, version 4V1R1 (newkur.dat) that is reflected by the Earth at the top of the atmosphere assuming a Lambertian surface.

All requirements/all performance requirements/all operational requirements: Refers to any performance characteristic or requirement in the ABI PORD, ABI UIID, and the GIRD .

CONUS-scanline: Refers to any line of pixels that extends in an EAST-WEST direction across the CONUS area in the fixed grid format of GOES ABI data.

CONUS: Defined as a nadir-viewed rectangle 8.0215 x 4.8129 degrees, 5000 East/West x 3000 North/South kilometers, approximately in the geographic area of 10N-60N latitude and 60W-125W longitude.

CONUS-swath: Refers to any swath used to generate CONUS-scanlines.

Derived Noise Equivalent Delta Radiance (NEDN): Refers to the NEDN required to meet the Noise Equivalent Delta Temperature (NEDT) specification or Signal-to-Noise Ratio (SNR) specification.

Detector sample or element: Refers to the output of a physical detector after the Analog-to-Digital (A/D) converter and Time Delay and Integration (TDI) processing, if necessary.

Eclipse: Defined as when the solar disk is completely occulted by the Earth or Moon, as viewed from the GOES satellite.

Fixed Grid Format: Refers to the idealized georeferenced positions for pixel locations. The fixed grid has the following characteristics:

- The fixed grid is rectified to a GRS80 geoid viewed from the idealized geostationary position.
- The pixels have the same angular separation for East/West and North/South.
- From the viewpoint of a right-hand coordinate system of the idealized geostationary satellite with its x-axis in the direction of the velocity and the z-axis pointed at nadir, the North/South angle is determined by a rotation about the x-axis and the East/West angle is determined by a rotation about the rotated y-axis.
- For the 0.64 micron channel the angular separation is 14 microradians.
- For the 0.47, 0.86, and 1.61 micron channels the angular separation is 28 microradians.
- For all other channels, the angular separation is 56 microradians.
- The center of the 14 microradian grid is offset by 7 microradians in both directions from the center of the 28 microradian grid such that four 14 microradian pixels fill the same area as a single 28 microradian pixel.
- The center of the 28 microradian grid is offset by 14 microradians in both directions from the center of the 56 microradian grid such that four 28 microradian pixels fill the same area as a single 56 microradian pixel.

- The ideal sub-satellite point is at the corner of a pixel on the 14, 28, and 56 microradian grids.
- Pixels within an angular radius of 8.66 degrees from the ideal geosynchronous satellite use the ideal satellite as the viewpoint.
- Pixels off the limb of the earth as observed from the actual satellite position use the actual satellite position as the viewpoint.
- Pixels between 8.66 degrees as observed by the ideal geosynchronous satellite position and pixels on the earth limb as observed from the actual satellite position use a viewpoint that is linearly interpolated between the ideal position of the satellite and the actual position of the satellite.

Full Disk: Defined as a 17.76 degree diameter circle centered at nadir, where 0.36 degree is added to the nominal Earth diameter of 17.4 degrees for non ideal orbital characteristics and anticipated uncompensated image motion.

Fully Functional Configuration: Being able to perform the following functions: scene radiance measurement; radiometric calibration; star sensing; on-orbit monitoring of calibration sources and instrument response changes; acquisition of sensor health and status data; generation of sensor, calibration, monitoring, health and status data streams; and reception and execution of command and control data.

Image: Refers to a full disk, CONUS, or mesoscale image in the fixed grid.

Image Navigation: Refers to the determination of the location of each image pixel relative to a fixed reference,
such as fixed-grid angle coordinates.

Image Registration: Refers to maintaining the spatial relationship between pixels within images, between images, and between channels.

Launch: The period of time between lift off and the separation of the GOES-R series satellite from the launch vehicle. The duration of launch is expected to be less than 2 hours long.

Mesoscale Region: Defined as the equivalent of a 1.6043 x 1.6043 degree, 1000 x 1000 kilometer nadir-viewed area.

Navigation Error: Refers to the angular error of locations in the resampled fixed-grid image.

Pixel: Applies to data samples after resampling during the ground processing.

Polarization Sensitivity: Defined as the ratio of the difference between maximum and minimum output to the sum of the maximum and minimum output obtained when the plane of incoming 100% linearly polarized radiation is rotated through 180 degrees.

Precision: Refers to the standard deviation of a statistically meaningful number of samples of a measurement.

Scanline: Refers to any line of pixels that extends in an East-West direction across the Earth or space in the fixed grid format of GOES ABI data.

Swath: Refers to any set of detector samples that are collected during a continuous scan of the detectors over the scene.

Transfer Orbit: The sequence of events that transpires to establish the GOES R series satellite on-station after the GOES R series satellite has separated from the launch vehicle.

1.8 Requirement Applicability

All requirements apply over the entire life of the ABI. All requirements in this ABI PORD apply to data after all ground processing except as indicated.

2 Applicable Documents

The following form a part of this specification to the extent specified herein.

A New Distortion Measure for Video Coding Blocking Artifacts. Wu, H. R., Proceedings from the 1996 International Conference on Communication Technology. Volume 2, May 5-7, 1996, Beijing, China. pp 658-651.

GOES-R General Interface Requirements Document, NASA-GSFC, Document Number 417-R-GIRD-0009

ABI Unique Instrument Interface Document (UIID), NASA-GSFC, Document Number 417-R-ABIUIID-0010

CCSDS Recommendation for Space Data System Standards, Lossless Data Compression, CCSDS 121.0-B-1, May 1997.

Structural Design and Test Factors of Safety for Spaceflight Hardware, NASA, Document Number NASA-STD-5001, June 21, 1996

General Specification for Assemblies, Moving Mechanical, for Space and Launch Vehicles, Document Number MIL-A-83577B, February 1, 1988

Space Mechanisms Handbook, Document Number NASA TP-1999-206988

General Environmental Verification Specification for STS and ELV Payloads, Subsystems and Components, Document Number GSFC GEVS-SE, June 1, 1996

Eastern and Western Range Policies and Procedures, Document Number EWR-127-1, Oct. 23, 2000

Standard General Requirements for Save Design and Operation of Pressurized Missile and Space Systems, Document Number MIL-STD-1522, Sept. 4, 1992

3 Sensor Requirements

3.1 Sensor Definition

The requirements in this ABI PORD pertain to the ABI ‘system’, which may include scanner, optics, detectors, signal processing electronics and software, and ground processing. The ABI contractor is not responsible for the whole ABI-GS, but certain specifications may require some level of ground processing after collection but before data distribution, i.e. decompression, re-sampling, and calibration.

3.1.1 ABI Modes

ABIPORD31	The ABI **shall** execute commands to individually enable and disable each autonomous function.
ABIPORD32	The ABI **shall** initiate all commanded mode transitions in no more than 20 seconds after receipt of command.
ABIPORD350	The ABI **shall** make limits and triggers of autonomous functions changeable by command.
ABIPORD466	The ABI **shall** transition from its current mode to any other mode without causing permanent damage to itself.
ABIPORD467	The ABI **shall** indicate the mode of the instrument in housekeeping telemetry.
ABIPORD471	The ABI **shall** provide command and housekeeping telemetry functions in all powered modes.

3.1.1.1 Safe Mode

ABIPORD469	The ABI **shal**l implement a Safe Mode.
ABIPORD470	The ABI **shall** be in a thermally and optically safe configuration for an indefinite period of time while in Safe Mode.
ABIPORD473	The ABI **shall** enter Safe Mode upon detection of internal faults capable of causing permanent damage to the instrument.

3.1.1.2 Normal Operational Mode

ABIPORD46	The ABI **shall** be in a fully functional configuration while in Normal Operational Mode.

3.1.1.3 Instrument Diagnostic Mode

ABIPORD53	The ABI **shall** implement an Instrument Diagnostic Mode.
ABIPOR	The ABI **shall** be in a fully functional configuration while in Instrument Diagnostic Mode.

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ABIPORD55 The ABI **shall** by command send selected channels while in Instrument Diagnostic Mode.

ABIPORD474 The ABI **shall** by command send the individual measurement for ground assessment in those cases where TDI data is digitally processed off the focal plane while in Instrument Diagnostic Mode.

ABIPORD475 The ABI **shall** by command send data from all detectors while in Instrument Diagnostic Mode.

ABIPORD476 The ABI **shall** by command send the same data both compressed and uncompressed if the data is capable of being compressed while in Instrument Diagnostic Mode.

ABIPORD477 The ABI **shall** by command send all bits from the A to D converter while in Instrument Diagnostic Mode.

ABIPORD478 The ABI **shall** by command perform electronic in-flight calibration while in Instrument Diagnostic Mode.

3.1.1.4 Outgas Mode

ABIPORD57 The ABI **shall** implement an Outgas Mode.

ABIPORD59 The ABI **shall** sublimate and evaporate contaminants from ABI hardware to prevent contamination from jeopardizing ABI performance while in Outgas Mode.

3.1.2 On-Orbit Operations

3.1.2.1 Zones of Reduced Data Quality

3.1.2.1.1 Operational Zone

ABIPORD82 The ABI **shall** meet all of its operational requirements for all pixels whose distance from the center of the uneclipsed portion of the sun is greater than the limits listed in the Operational Zones Table.

Operational Zones Table

Channel	Outer Limit
Low light	10°
All others	7.5°

3.1.2.1.2 Restricted Zone

ABIPORD84 For all pixels whose distance from the center of the uneclipsed portion of the sun is between the inner and outer limits shown in the Restricted Zones Table, the ABI **shall** meet all requirements, except for a two times degradation of the SNR and NEDT requirements stated in requirement number ABIPORD148, a two times degradation of the absolute accuracy requirement stated in ABIPORD219, and a navigation relaxation as described in ABIPORD202.

SNR, MTF, INR, Calibration Accuracy and Low Light requirements for the Visible/Near Infrared (less than 3 microns) channels are not applicable whenever any point on the earth falls within the restricted zone as defined in the Restricted Zones Table with the exception that for this sentence only, the restricted zone is applicable for both the eclipsed and uneclipsed sun.

Restricted Zones Table

Channel	Inner Limit	Outer Limit
3.9 micrometers	5°	7.5°
All others	3°	7.5°

3.1.2.2 Scanning Across the Sun

ABIPORD87 The ABI **shall** be able to scan across the sun at its normal scan rate two times within 30 seconds or less without interrupting normal imaging operations or sustaining damage.

3.1.2.3 Eclipse

ABIPORD89 The ABI **shall** be capable of continuous operation through eclipse periods.

ABIPORD90 During eclipse periods, for all channels with wavelengths greater than 3 microns, the ABI **shall** meet all requirements, except as noted in requirement number ABIPORD202.

3.1.2.4 Operations After Maneuvers

3.1.2.4.1 Yaw Flip

ABIPORD93 The ABI **shall** meet the channel definitions, NEDT, dynamic range and Radiometric Accuracy and Precision sections within 1 hour after the spacecraft interface has returned to being within specification following a yaw flip.

ABIPORD94 The ABI **shall** meet INR requirements within 1 day after the spacecraft attitude has returned to being within specification following a yaw flip.

3.1.2.4.2 Stationkeeping

ABIPORD96 The ABI **shall** meet all radiometric, coverage and INR requirements within 60 minutes after the spacecraft interface has returned to being within specification following spacecraft stationkeeping maneuvers.

3.1.2.4.3 Post Storage Activation

ABIPORD98 The ABI **shall** meet all requirements within 5 days of ABI turn on after post storage activation for an ABI with passively cooled detectors and 3 days for an ABI with actively cooled detectors.

3.1.2.5 Detector Operating Temperatures

ABIPORD100 The ABI detector operation temperatures **shall** be selectable by command.

ABIPORD101 The ABI detector control temperature **shall** be in 1K increments or smaller.

ABIPORD479 The ABI detector control temperature **shall** be at least +10K/-5K of the nominal operational temperature.

ABIPORD102 The precision on the control temperatures of the ABI detector **shall** be les than +/- 0.5 K.

3.2 Sensor Characteristics

3.2.1 Image Characteristics

3.2.1.1 Scan Modes

ABIPOR D107 Routine operations, such as uploading commands and data to the ABI, **shall** not interfere with data collection in any scan mode.

ABIPOR D320 The ABI **shall** be capable of interrupting current operations by command and starting the acquisition of a new image, after an image coordinate upload, within 30 seconds.

3.2.1.1.1 Scan Mode 3

ABIPOR D109 The ABI **shall** acquire concurrently:

- Full Disks at 15 minute intervals,
- CONUS images at 5 minute intervals, any of which may be extracted from the full disk images if the timing is correct,
- A Mesoscale image at 30 second intervals,
- Any other observations requried to meet radiometric and INR requirements.

3.2.1.1.2 Scan Mode 4

ABIPOR D111 The ABI **shall** acquire concurrently:

- Full Disks at 5 minute intervals,
- Any other observations required to meet radiometric and INR requirements.

3.2.1.1.3 Full Disk

ABIPOR D113 In Mode 3, an image of the Full Disk **shall** be acquired with all corresponding pixels in consecutive frames spaced at an average time of 15 minutes with a peak deviation of ± 30 seconds.

ABIPOR D114 In Mode 4, an image of the Full Disk **shall** be acquired with all corresponding pixels in consecutive frames spaced at an average time of 5 minutes with a peak deviation of ± 5 seconds.

3.2.1.1.4 CONUS

ABIPOR D116 In Mode 3, an image of the CONUS area **shall** be acquired with all corresponding pixels in consecutive frames spaced at an average time of 5 minutes with peak deviation of +/- 30 seconds. The ABI design may assume that the spacecraft x axis is parallel to the Earth's equator within the accuracy as stated in the GIRD.

3.2.1.1.5 Mesoscale

ABIPOR D118 In Mode 3, an image of a Mesoscale region viewed anywhere on the disk **shall** be acquired with all corresponding pixels in consecutive frames spaced at an average time of 30 seconds apart with a peak deviation of +/- 5 seconds.

3.2.1.2 Flexible and Efficient Scan Pattern

ABIPOR D120 The ABI **shall** be designed such that the scan patterns are programmable on-orbit.

ABIPORD121	The ABI **shall** accept fixed grid coordinates for all Scan Modes.
ABIPORD123	In addition to Full Disk scans, the ABI **shall** have the capability to program CONUS scans.
ABIPORD124	In addition to Full Disk scans, the ABI **shall** have the capability to program Mesoscale scans.
ABIPORD125	The ABI **shall** autonomously adjust the Scan Pattern to avoid scanning within a ground definable angle from the center of the sun.
ABIPORD126	If star sensing is used, the ABI **shall** autonomously onboard compute the position of stars and adjust the scan pattern to acquire them (with any adjusted scan pattern still meeting all other requirements in this document).
ABIPORD127	The scan pattern **shall** be definable by ground modifiable parameters such that full disk, CONUS, and mesoscale images, other image regions and sizes, space looks, IR calibration, and star sensing are performed at any user-defined intervals that are consistent with the scan rates and slew rates used in predefined scan modes. These data items will be uploaded during earlier operations and activated with a single command.

3.2.1.3 Field of Regard

ABIPORD129	The ABI's unvignetted Field of Regard (FOR) **shall** include a circle of at least 20 degrees in diameter with its center at the sub-satellite point and accounting for alignment errors as described in the GIRD. The ABI's unvignetted FOR **shall** include a solid angle that is at least 2 degrees E/W by 1 degree N/S, and is at least 3 degrees from the limb of the Earth.

3.2.1.4 Simultaneity

ABIPORD132	Corresponding pixels in all spectral channels **shall** be calculated from detector samples collected within 5 seconds of each other.
ABIPORD133	All adjacent North/South pixels **shall** be calculated from detector samples collected within 30 seconds of each other.
ABIPORD134	At least 99.5 % of adjacent East/West pixels **shall** be calculated from detector samples collected within 15 seconds of each other.

3.2.1.5 Data Timeliness

ABIPORD136	The ABI image products **shall** have a maximum delay of 1 minute (TBR) after ground receipt of all samples within the image for a CONUS image, 30 seconds (TBR) for a Mesoscale image and 5 minutes for a Full Disk image (TBR).

3.2.1.6 Data Acquisition Direction

ABIPORD140	The ABI **shall** acquire data in a predominantly East/West and/or West/East direction.
ABIPORD141	Image acquisition **shall** begin with the northern most coordinates and proceed south.

3.2.1.7 Data Collection Overlap

ABIPORD143	The ABI **shall** generate each pixel from raw samples contained in single swath.

3.2.2 Channel Definitions, NEDT, Dynamic Range

3.2.2.1 Baseline

ABIPOR D147 The ABI **shall** collect imagery in the following 16 channels designated by their center wavelength in microns: 0.47, 0.64, 0.86, 1.38, 1.61, 2.26, 3.9, 6.185, 6.95, 7.34, 8.5, 9.61, 10.35, 11.2, 12.3, 13.3.

ABIPOR D148 The ABI **shall** meet the SNR, and NEDT listed in the following ABI Radiometric Precision Table.

ABI Radiometric Precision Table

Center Wavelength Microns	NEDT @300K +/- 1K (K)	NEDT @240K +/- .5K (K)	SNR at 100% albedo
0.47	-	-	SNR=300:1
0.64	-	-	SNR=300:1
0.86	-	-	SNR=300:1
1.38	-	-	SNR=300:1
1.61	-	-	SNR=300:1
2.26	-	-	SNR=300:1
3.9	0.10	1.4	
6.185	0.10	0.4	
6.95	0.10	0.37	
7.34	0.10	0.32	
8.5	0.10	0.27	
9.61	0.10	0.22	
10.35	0.10	0.21	
11.2	0.10	0.19	
12.3	0.10	0.18	
13.3	0.30	0.48	

ABIPOR D149 The ABI **shall** meet the dynamic range listed in the following ABI Dynamic Range Table for detector samples.

ABI Dynamic Range Table

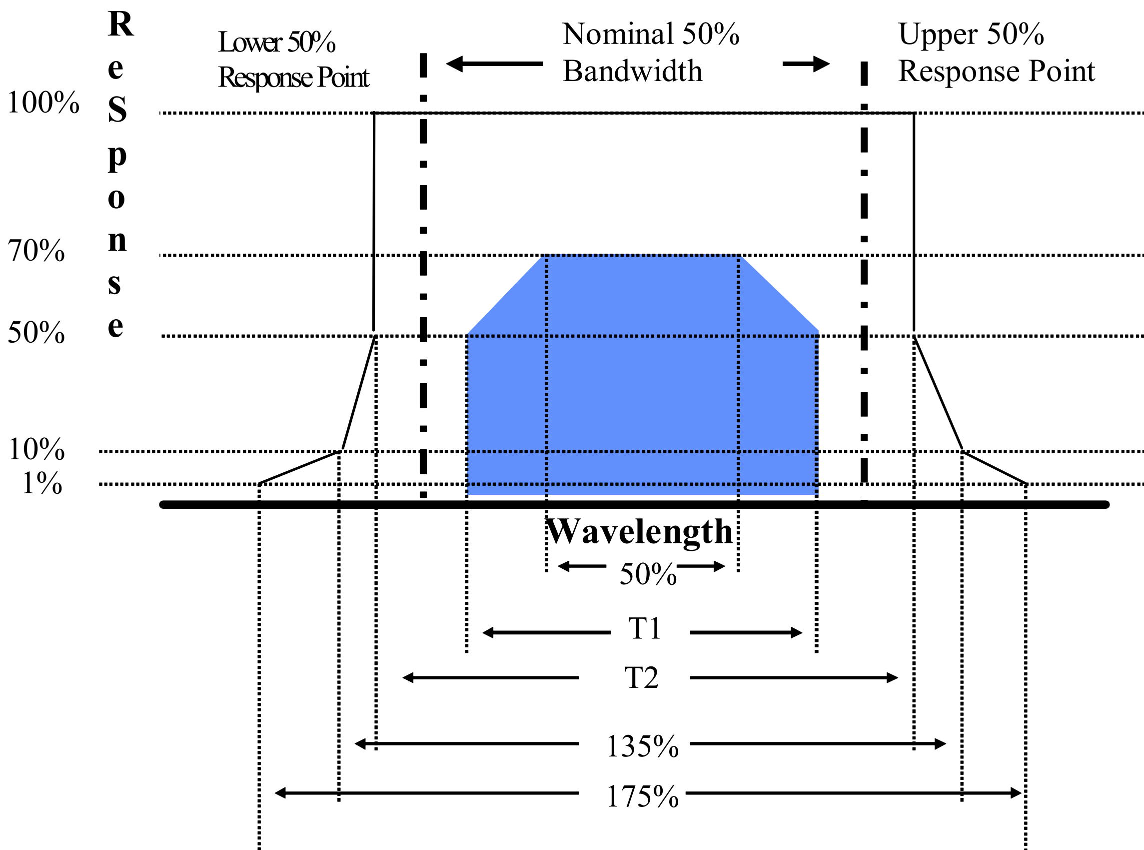
Center Wavelength Microns	Scene T_{min} (K)	Scene T_{max} (K)	N_{max} ($mW/m^2/sr/cm^{-1}$)
0.47	N/A	-	14.4
0.64	N/A	-	21.1 1.05
0.86	N/A	-	22.8
1.38	N/A	-	21.7
1.61	N/A	-	20.0
2.26	N/A	-	12.1
3.9	4	400	
6.185	4	300	
6.95	4	300	
7.34	4	320	
8.5	4	330	
9.61	4	300	
10.35	4	330	
11.2	4	330	
12.3	4	330	
13.3	4	305	

3.2.2.2 System Spectral Response

3.2.2.2.1 Spectral Response Envelope

ABIPORD154 The ABI system spectral response **shall** conform to the envelope per ABIPORD 157 and the values in ABIPORD158. The values T1 and T2 in ABIPORD157 are determined by adding and subtracting the tolerances listed in ABIPORD158 to the upper and lower 50% response points. The percentages listed in ABIPORD157 are of the nominal bandwidths in ABIPORD158.

ABIPORD155 When viewing the four government-supplied simulated upwelling radiance data sets in Appendix A, the brightness temperature error due to the uncertainty in the spectral response between the 1% response points **shall** be less than 1K for all channels with center wavelength greater than 3 microns.


Response
Lower 50%
Response Point
Nominal 50%
Bandwidth
Upper 50%
Response Point
100%
70%
50%
10%
1%
Wavelength
50%
T1
T2
135%
175%

Nominal Center Wavelength (μm)	Lower 50% Response Point	Upper 50% Response Point	Nominal 50% Bandwidth
Baseline Channels			
0.47	0.45 +/- 0.01	0.49 +/- 0.01	0.04
0.64	0.59±0.01	0.69±0.01	0.10
0.86	0.84±0.01	0.88±0.01	0.04
1.38	1.365±0.005	1.395±0.005	0.03
1.61	1.58±0.01	1.64±0.01	0.06
2.26	2.235±0.01	2.285±0.01	0.05
3.9	3.80±0.05	4.00±0.05	0.20
6.185	5.77±0.03	6.60±0.03	0.83
6.95	6.75±0.03	7.15±0.03	0.40
7.34	7.24±0.02	7.44±0.02	0.20
8.5	8.3±0.03	8.7±0.03	0.40
9.61	9.42±0.02	9.8±0.03	0.38
10.35	10.1±0.1	10.6±0.1	0.50
11.2	10.8±0.1	11.6±0.1	0.80
12.3	11.8±0.1	12.8±0.1	1.0
13.3	13.0±0.06	13.6±0.06	0.6

3.2.2.2.2 Within Channel Spectral Response Uniformity

ABIPORD160 When viewing the simulated upwelling radiance data sets in Appendix A and when viewing the default solar irradiance spectrum from MODTRAN version 4V1R1 (newkur.dat) with the assumption that clouds have Lambertian reflectance with an albedo not less than 50%, the variation in radiance measured between the 1% response points in each spectral channel, due to spectral differences over the focal plane, **shall** be less than the derived NEDN for all channels.

3.2.2.2.3 Out-of-Band Response

ABIPORD164 The out-of-band response is defined in the equation as one minus the integrated response between the 1% response points divided by the integrated response from 0.3 microns to 20 microns. Out-of-band response **shall** be less than 0.1% of the signal for the 1.38 micron channel and 1% of the total signal for all other channels when viewing either a 300 K blackbody (for channel wavelengths greater than 3 microns) or a 100% albedo scene above the atmosphere assuming no attenuation.

Out-of-Band Response Equation

$$\text{(Equation 1)}\quad 1-\left(\int_{-\lambda_{1\%}}^{+\lambda_{1\%}} N(\lambda)R(\lambda)d\lambda \Big/ \int_{\lambda_{0.3\,\mu m}}^{\lambda_{20\,\mu m}} N(\lambda)R(\lambda)d\lambda \right) \leq 0.01 \quad \text{where}$$

$N(\lambda)$ = 300 K blackbody or 100% albedo and
$R(\lambda)$ is the channel relative spectral response

3.2.2.3 Low Light Visible Channel

ABIPORD166 The ABI **shall** include a low light level (5% albedo) visible (0.64 microns) imaging capability at 50:1 SNR with performance equivalent to the 0.64 microns visible channel except as noted in requirements ABIPORD 82, and 84.

3.2.3 Spatial Resolution and Sampling

3.2.3.1 System Modulation Transfer Function

ABIPORD171 The ABI spatial resolution is defined by the sensor system sinusoidal MTF. The following MTF values (exact specification is in cycles/rad) are consistent with 0.5 kilometer resolution in the 0.64 micron channel, 1.0 kilometer resolution in the 0.47 micron channel, 1.0 kilometer resolution in the 0.86 micron channel, 1.0 kilometer resolution in the 1.61 micron channel, and 2.0 kilometer resolution in all other channels. The spatial frequencies, when referenced to kilometers, are measured at nadir. The ABI system MTF **shall** meet the requirements in the following tables over the Full Disk image area, in both East/West and North/South directions, after any ground processing, in the presence of jitter, when averaged over all resampling phases of the detector sample grid to pixel grid, and after any lossy compression/decompression.

ABI MTF Emissive Channel Requirements Table

All channels greater than 3 microns

Spatial Period	Spatial Frequency	System MTF
km/cyc	cyc/rad	
16.0	2250	0.84
8.0	4500	0.62
5.333	6750	0.39
4.0	9000	0.22

ABI MTF Reflective Channel Requirements Table

0.64 micron channel			0.47, 0.86, 1.61 micron channels			1.38 and 2.26 channels		
Spatial Period	Spatial Frequency	System MTF	Spatial Period	Spatial Frequency	System MTF	Spatial Period	Spatial Frequency	System MTF
km/ cyc	cyc/rad		km/ cyc	cyc/rad		km/ cyc	cyc/rad	
4.0	9000	0.90	8.0	4500	0.90	16.0	2250	0.90
2.0	18000	0.73	4.0	9000	0.73	8.0	4500	0.73
1.333	27000	0.53	2.666	13500	0.53	5.333	6750	0.53
1.0	36000	0.32	2.0	18000	0.32	4.0	9000	0.32

3.2.3.2 Spatial Response Uniformity

ABIPORD178 Effects of co-registration are assumed to be negligible for the purposes of these requirements (ABIPORD 178 through 182).

The normalized radiance difference due to spatial response differences between corresponding pixels in any two spectral channels with a center wavelength greater than 3 microns located X (continuous variable) microradians from the edge of a 1000 by 1000 microradian or larger target with radiance equal or greater than 300 K surrounded by a large region of radiance equal to or less than 240 K **shall** agree to within 4 % of the step radiance difference for an rms over the sampling-to-edge phasing and the channel-to-channel relative phasing. The calculation of this normalized difference is expressed in equation form below.

Here the overbar represent an average over multiple samples located well away from the edge. This normalized radiance difference due to spatial response differences applies in all four directions, i.e. left of, right of, above, and below the target box. The values of X include all distances between +84 microradians and -84 microradians.

$$L_{norm} = \left(L - \overline{L_{240}}\right) \Big/ \left(\overline{L_{300}} - \overline{L_{240}}\right)$$

$$S_{norm} = \left(S - \overline{S_{240}}\right) \Big/ \left(\overline{S_{300}} - \overline{S_{240}}\right)$$

$$Diff = L_{norm} - S_{norm}$$

ABIPORD179 Any efforts to blur or enhance channel resolution to match that of other emissive (greater than 3 microns) channels **shall** be performed in ground system software, not within the ABI instrument.

ABIPORD180 The reflectance difference due to spatial response differences between corresponding pixels in any two spectral channels with a center wavelength of 0.47, 0.86 and 1.61 microns located X (continuous variable) microradians from an edge of a 1000 by 1000 microradian or larger target with radiance equal to N_{max} (see requirement ABIPORD149) surrounded by a large region of radiance equal to or less than 5% N_{max} **shall** be less than 4% of the step function for an rms over the sampling-to-edge phasing and the channel-to-channel relative phasing.

ABIPORD181 The reflectance difference due to spatial response differences between corresponding pixels in the two spectral channels with center wavelengths of 1.38 and 2.26 microns located X (continuous variable) microradians from an edge of a 1000 by 1000 microradian or larger target with radiance equal to N_{max} (see requirement ABIPORD 149) surrounded by a large region of radiance equal to or less than 5% N_{max} **shall** be less than 4% of the step function for an Root Mean Square (RMS) over the sampling-to-edge phasing and the channel-to-channel relative phasing. This reflectance difference due to spatial response differences applies in all four directions, i.e. left of, right of, above, and below the target box. The values of X include all distances between +84 microradians and -84 microradians.

ABIPORD182 Any efforts to blur or enhance channel resolution to match that of other reflective (less than 3 microns) channels **shall** be performed in ground system software, not within the ABI.

3.2.3.3 Ringing from a Sharp Edge

ABIPORD185 For both the North/South and East/West edges, the ABI **shall** not overshoot the top of an edge or undershoot the bottom of edge by more than 2% of the height of the edge where:

- the height and the overshoot/undershoot are measured in radiance units.

- the edge delineates a 10% albedo region from a 90% albedo region for channels less than 3 microns.

- the edge delineates a 240K region from a 300K region for channels greater than 3 microns.

- the overshoot is averaged over all resampling phases of the detector sample grid to pixel grid and edge position to detector sample grid.

3.2.4 Image Navigation and Registration

3.2.4.1 INR Scope

Mission-level INR requirements apply to pixels and encompass the combined system performance of the ABI, spacecraft and ground processing system.

3.2.4.2 Star Sensing

ABIPORD194 If star sensing is employed onboard, the ABI **shall** have an on-board star catalog which is loadable and modifiable from the ground.

ABIPORD195 If star sensing is employed onboard, the ABI **shall** be capable of being commanded to acquire an ABI-GS list of target stars that will be within the nominal FOR for the next 26 hours

3.2.4.3 INR Performance Requirements

All INR requirements listed herein refer to location error of the ABI fixed-grid pixels; i.e., the requirements apply to the end-to-end system, taking all instrument, spacecraft, and ground processing effects into account. Unless otherwise specified, all INR requirements in this document are specified as North/South and East/West angles, in microradians, 3-sigma, and refer to all hours of operation.

In addition, 3-sigma is interpreted as the average +/- 3 times the square root of the variance for a population of 100 consecutive observations.

3.2.4.3.1 Navigation

ABIPORD201 The ABI navigation error **shall** not exceed +/- 21 microradians except during eclipse periods.

ABIPORD202 For up to a four hour period that includes a total or partial eclipse of the sun, the ABI navigation requirement in ABIPORD201 **shall** be relaxed to +/- 32 microradians. The phasing of the four hour relaxation relative to the eclipse may be design-specific and will be recommended by the ABI contractor.

3.2.4.3.2 Frame-to-Frame Registration

ABIPORD204 Frame-to-frame registration error **shall** not exceed ±16 microradians for the 0.47, 0.64, 0.86, and 1.61 micron channels. Frame-to-frame registration error is the difference in navigation error for any given pixel in two consecutive images within the same channel.

ABIPORD205 Frame-to-frame registration error **shall** not exceed ±21 microradians for all other channels.

3.2.4.3.3 Within Frame Registration

ABIPORD207 Within an image in the same channel, any two pixels **shall** be separated by the known fixed distance to within +/- 21 microradians.

3.2.4.3.4 Swath-to-Swath Registration Registration

ABIPORD209 Swath-to-swath registration error **shall** not exceed +/- 5.2 microradians, where swath-to-swath registration error is the relative location error of adjacent pixels across a swath boundary within the same channel.

3.2.4.3.5 Channel-to-Channel Registration

ABIPORD211 Channel-to-channel registration error, or co-registration, is the difference in navigation errors between spectral channels for any given pixel in the same frame. The channel-to-channel registration requirements depend on the fixed-grid resolutions of the channels. Co-registration between channels having different resolutions is defined by centroiding a square grid of the finer pixels to determine a "mean" pixel equal in extent to the coarser pixel.
Co-registration errors between any two ABI spectral channels **shall** not exceed the values shown in the Channel-to-Channel Registration table.

Channel-to-Channel Registration Table

	2-km	**1-km**	**0.5-km**
2-km	6.3 microradian	6.3 microradian	6.3 microradian
1-km	--	5.2 microradian	5.2 microradian

3.2.5 Radiometric Accuracy and Precision

3.2.5.1 IR Channel Calibration and Accuracy for Wavelengths Greater than 3 Microns

3.2.5.1.1 Full Aperture Calibration

ABIPORD217 The ABI **shall** have full system, end-to-end, and full aperture on-board calibration for the IR channels with wavelengths greater than 3 microns.

3.2.5.1.2 Absolute Accuracy

ABIPORD219 The ABI data **shall** be calibrated to an absolute accuracy of +/- 1 K at a 300 K reference temperature, traceable to the National Institute of Standards and Technology (NIST) radiometric and temperature standards through the application of NIST transfer radiometers to the ground calibration sources.

3.2.5.2 Repeatability

All repeatability requirements will be evaluated while viewing a stable, uniform calibration source over expected geostationary environmental conditions and calibration frequency. Channels with wavelengths less than 3 microns will be characterized as if viewing a 100% albedo calibration source. Channels with wavelengths greater than 3 microns will be characterized as if viewing a 300 K temperature calibration source.

3.2.5.2.1 Pixel-to-Pixel

ABIPORD227 For all channels, while viewing the scenes described in the Repeatability section, the ABI **shall** have a pixel-to-pixel repeatability less than the derived NEDN.

The pixel-to-pixel repeatability is calculated as follows: for each 3 row by 10 column subset of the image the row average is calculated for each row, the RMS of the row averages is then calculated and must be less than the derived NEDN. This value is then averaged N_{image} times where N_{image} is the number of samples required to state at the 90% confidence level that the requirement has been met

Pixel-to-Pixel Equation

$$\text{Derived NEDN} > \frac{1}{\text{N}_{\text{image}}} \sum_{j=0}^{N_{image}-1} \sqrt{\tfrac{1}{3}\sum_{i=0}^{2}\left(\overline{R_i} - \overline{R}\right)^2}$$

where

$\overline{R} = \frac{1}{30}\sum_{i=0}^{2}\sum_{j=0}^{9} P_{i,j}$ is the mean for 30 pixels.

$\overline{R}_i = \frac{1}{10}\sum_{j=0}^{9} P_{i,j}$ is the row mean for row i.

$P_{i,j}$ is the resampled pixel value for row i, column j

This equation applies to be met for all possible locations on the full disk.

3.2.5.2.2 Swath-to-Swath

ABIPORD229 For each channel with a wavelength greater than 3 microns, while viewing the scenes described in ABIPORD223, the difference in calibrated pixel radiance between swath boundaries in a resampled image **shall** be less than the derived NEDN. The swath-to-swath repeatability is evaluated by computing the RMS of the difference of neighboring row means at swath boundaries for CONUS-wide images. NBoundaries is the number of boundaries required to state at the 90%

confidence level that the requirement has been met. In the resampled image, a boundary is where neighboring North/South pixels come from different swath scans.

Swath-to-Swath Equation

$$\text{Derived NEDN} > \sqrt{\frac{1}{NBoundaries}\sum_{i=0}^{NBoundaries-1}(\overline{R}_{North}-\overline{R}_{South})^2}$$

where

$$\overline{R}=\frac{1}{M}\sum_{i=0}^{M-1}P_{0,i} \quad \text{is the mean of a one pixel high row of M pixels long}$$

3.2.5.2.3 Channel-to-Channel

ABIPOR D231 For each channel with a wavelength greater than 3 microns, while viewing the scenes described in Repeatability section, the ABI **shall** have a channel-to-channel repeatability less than 0.2 Kelvin. The channel-to-channel repeatability is evaluated by computing the RMS of CONUS image mean differences between each channel pair, over a series of NImages. NImages is the number of images required to state at the 90% confidence level that the requirement has been met.

The calculation is done in radiance units and converted to temperature in the final step.

Channel-to-Channel Equation

$$0.2K > \sqrt{\frac{1}{N\,\mathrm{Im}ages}\sum_{r=0}^{N\,\mathrm{Im}ages-1}(\bar{I}_{r,c1}-\bar{I}_{r,c2})^2}$$

where

$$c1, c2 = \text{Channel pair with wavelengths greater than 3 microns}$$

$$\bar{I}=\frac{1}{NM}\sum_{i,j=0}^{N-1,M-1}P_{i,j} \quad \text{is the mean of a CONUS size image}$$

3.2.5.2.4 Image-to-Image

ABIPOR D233 For each channel with a wavelength greater than 3 microns, while viewing the scenes described in Repeatability section, the ABI **shall** have an image-to-image repeatability of less than 0.2 Kelvin. The image-to-image repeatability is evaluated by computing the RMS of consecutive CONUS image differences over a series of NImages for each channel. NImages is the number of images required to state at the 90% confidence level that the requirement has been met.

The calculation is done in radiance units and converted to temperature in the final step.

Image-to-Image Equation

$$0.2K > \sqrt{\frac{1}{\text{NImages - 1}} \sum_{r=0}^{N\text{Im}ages-2} (\bar{I}_{r+1} - \bar{I}_r)^2}$$

where

$$\bar{I} = \frac{1}{NM} \sum_{i,j=0}^{N-1,M-1} P_{i,j} \quad \text{is the mean of a CONUS size image}$$

3.2.5.2.5 Blackbody Calibration-to-Calibration

ABIPORD235 For each channel with a wavelength greater than 3 microns, while viewing the scenes described in Repeatability section, the ABI **shall** have a calibration-to-calibration repeatability of less than 0.2 Kelvin. The calibration-to-calibration repeatability is evaluated by computing the RMS of consecutive CONUS image mean differences with a blackbody calibration event between the images. Ncals is the number of image pairs required to state at the 90% confidence level that the requirement has been met.

The calculation is done in radiance units and converted to temperature in the final step.

Blackbody Calibration-to-Calibration Equation

$$0.2K > \sqrt{\frac{1}{NCals} \sum_{r=0}^{NCals-1} (\bar{I}_{before} - \bar{I}_{after})^2}$$

where

$$\bar{I} = \frac{1}{NM} \sum_{i,j=0}^{N-1,M-1} P_{i,j} \quad \text{is the mean of a CONUS size image}$$

3.2.5.3 Coherent Noise

ABIPORD238 For all channels, while viewing the scenes described in Repeatability section, the ABI **shall** have no spatial coherent noise spectral component exceedances. The spatial coherent noise is defined as the 2-D Fourier transform of the pixels of a full disk sized region including all calibration and sampling. An exceedance is defined as any spatial frequency whose magnitude is greater than six times the RMS value of the 100 bin region centered on the bin of interest.
Note: The width of bin is defined by the fixed grid spacing.

3.2.5.4 Calibration of Channels Less Than 3 Microns

3.2.5.4.1 On-Board Calibration

ABIPORD246 The ABI **shall** have an on-board calibration capability for the visible and near Infrared (IR) (less than 3 microns) channels that provides: absolute accuracy of +/- 3% or less at 100% albedo.

ABIPORD481 The ABI **shall** have an on-board calibration capability for the visible and near IR (less than 3 microns) channels that provides RMS repeatability of 0.2% or less. This requirement is met when no fewer than 20 independent calibrations are performed as closely as possible together in time and the RMS variation in each calibration coefficient is less than the specified level.

ABIPORD482 The ABI **shall** have an on-board calibration capability for the visible and near IR (less than 3 microns) channels that provides drift in absolute calibrated radiances of 0.5% over the ABI lifetime. This requirement is met when the average change in calibrated scene radiance for scenes collected immediately before or after a calibration event do not change by more than 0.5% using the pre- and post-calibration coefficients for 99% of pixels in a full disk image.

ABIPORD248 The calibrations in ABIPORD246, ABIPORD481, and ABIPORD482 **shall** be NIST traceable prior to launch through the application of NIST transfer radiometers to the ground calibration sources.

3.2.5.5 Spatial Uniformity of Data

ABIPORD326 The ABI **shall** have less than 0.1% change in response in the calibrated pixel data over the field of regard while viewing a constant scene specified in ABIPORD223..

3.2.5.6 Crosstalk

3.2.5.6.1 Channel-to-Channel

ABIPORD255 The ABI channel-to-channel (electrical, optical, spatial, spectral,) crosstalk **shall** be less than the derived NEDN. Channel-to-channel crosstalk is defined as the change in any channel output when one channel's illumination is changed from 0.1 N_{max} to a radiance of N_{max} while all other channels remain illuminated at a radiance level less than 0.1 N_{max} (ABIPORD149).

3.2.5.6.2 Within Channel

ABIPORD257 Non-adjacent pixel to pixel within channel cross talk, not including diffraction, **shall** be less than the derived NEDN. Within channel crosstalk is defined as the change in any non-adjacent pixel when one pixel’s radiance is changed from 0.1 N_{max} to a radiance of N_{max} (ABIPORD149) while all other pixels in the same band remain illuminated at a radiance level less than 0.1 N_{max}.

3.2.5.7 Blooming

ABIPORD259 In all directions from the edge of a 500 by 500 microradian bright target at twice N_{max} (ABIPORD149), all detector outputs in channels with center wavelengths less than 2.0 microns **shall** recover to normal operation within 600 microradians.

ABIPORD260 In all directions from the edge of a 50 by 50 microradian bright target at twice maximum scene radiance, all detector outputs in channels with center wavelengths of 3.9 microns and 2.26 microns **shall** recover to normal operation within 500 microradians.

3.2.5.8 Quantization Step Size

ABIPORD263 The quantizing step size for all detector samples **shall** be less than 0.5 the derived NEDN

3.2.5.9 Electronic In-Flight Calibration

ABIPORD267 A system for calibrating and checking the linearity of the electronics and analog-to-digital converters **shall** be incorporated.

ABIPORD268 The calibration signal input non-linearity **shall** be such that all points within the dynamic range vary from a linear best fit by no more than 0.1% of N_{max} in ABIPORD149.

ABIPORD269 The calibration signal input dynamic range **shall** be greater than the dynamic range specified in ABIPORD149.

ABIPOR The calibration signal of requirement ABIPORD267 **shall** be inserted as close to the detector

D270 output signal as practicable in the electronics chain.

3.2.5.10 Polarization of Channel Less Than 3 Microns

3.2.5.10.1 Polarization Control

ABIPORD274 ABI channels with wavelengths less than 2 microns **shall** have less than 4% polarization sensitivity to the incoming light at all Earth-viewing angles.

ABIPORD275 The difference in polarization sensitivity to polarization between channels with wavelengths less than 2 microns **shall** be less than 2% at all Earth-viewing angles.

3.2.6 System Dynamic Range and Linearity

ABIPORD282 The ABI **shall** have linear radiometric response, before calibration, such that all points within the dynamic range vary from a linear best fit by no more than 1% of N_{max} in ABIPORD149 except for the 3.9 micron channel**.**

ABIPORD283 For the 3.9 micron channel, the ABI **shall** have linear radiometric response, before calibration, such that all points within the dynamic range vary from the linear best fit by no more than 1% at 375K except for the range between 375K and 400K.

3.2.7 Data Compression

The ABI **shall** perform lossless data compression on the data. The ABI may perform lossy data compression on the 0.47, 0.64, 0.86, and 1.61 micron channels.

3.2.7.1 Lossless Data Compression

ABIPORD286 Lossless data compression **shall** be in accordance with CCSDS 121.0-B-1.

3.2.7.2 Compression of the 0.47, 0.64, 0.86 and 1.61 Micron Channels

ABIPORD288 If performed, lossy compression **shall** meet the requirements listed in the Lossy Compression Requirement Table.

Lossy Compression Requirement Table

Metric	Definition	Requirement
Peak SNR	$$PSNR = 20\log_{10}\left(\frac{N_{\max}}{\sqrt{\frac{1}{MN}\sum_{i=1}^{N}\sum_{j=1}^{M}(X_{i,j}-\overline{X}_{i,j})^2}}\right)$$ where $N_{\max}$ is the maximum scene radiance in ABIPORD149, $X_{i,j}$ is the orginal image, $\overline{X}_{i,j}$ is the reconstructed image, and MN are the image dimensions	PSNR >= 50 dB
Correlated noise	$M=0.5*(M_{hGBIM}+M_{vGBIM})$, where M_{hGBIM} and M_{vGBIM} are defined in [1]	$\frac{M_{RC}}{M_{ORIG}} < 1.1$ where M_{RC} is the metric for the reconstructed image, and M_{ORIG} is for the original image

[1] H.R. Wu, "A New Distortion Measure for Video Coding Blocking Artifacts," in Proceedings of the 1996 International Conference on Communication Technology, vol. 2, May 5-7, 1996, Beijing, China, pp. 658-661.

ABIPORD290 If lossy data compression is performed, the ABI **shall** be capable of switching between lossy and lossless compression on orbit although the average data rate requirement does not apply when the ABI is commanded to send lossless data.

ABIPORD291 Command activation of lossy compression capability **shall** be on a channel-by-channel basis.

ABIPORD293 Solar reflective calibration data and space look data **shall** always be lossless compressed or uncompressed.

3.2.8 Lifetime

ABIPORD301 The ABI **shall** be designed to have Reliability (R) of at least 0.6 after 10 years of design life, preceded by up to 5 years of ground storage and up to 5 years of on-orbit storage.

ABIPORD309 The ABI **shall** be designed to have Mean Mission Duration (MMD) of 8.4 years.

ABIPORD460 The ABI **shall** have redundancy to eliminate all credible single-point failures.

ABIPORD461 The ABI redundant components **shall** be selectable by external command only.

ABIPORD462 The ABI units of any Flight Model **shall** be interchangeable, without modification, with the equivalent units of any other ABI Flight Model.

ABIPOR The ABI **shall** withstand without damage the sudden removal of operational power.

D493

3.2.9 Mechanical Requirements

ABIPOR D332 Each ABI unit structure **shall** possess sufficient strength, rigidity and other characteristics required to survive the critical loading conditions that exist within the envelope of handling and mission requirements

3.2.9.1 Design Limit Loads

ABIPOR D355 The structure **shall** be capable of withstanding all limit loads without loss of any required function.
Limit loads are defined as all worst case load conditions including temperature effects from the environments expected during all phases of the structure's service life including manufacturing, ground handling, transportation, environmental testing, integration, pre-launch, launch and on-orbit operations and storage.

3.2.9.2 Nonlinear Loads

ABIPOR D357 The ABI structures **shall** be capable of withstanding redistribution of internal and external loads resulting from nonlinear effects including deflections under load.

3.2.9.3 Yield Strength

ABIPOR D359 The ABI structures **shall** be able to support yield loads without detrimental permanent deformation. Yield loads are limit loads multiplied by the appropriate prototype yield factor of safety specified in NASA-STD-2001. For structural elements containing beryllium or beryllium alloys, the prototype yield factor of safety is 1.4.

ABIPOR D360 While subjected to any operational load up to yield operational loads, the resulting deformation **shall** not interfere with the operation of the ABI flight units. Operational load is defined as the expected on-orbit loads while the ABI is operating.

3.2.9.4 Ultimate Strength

ABIPOR D362 The ABI structures **shall** be able to support ultimate loads without fracture or collapse for at least 3 seconds including ultimate deflections and ultimate deformations of the flight unit structures and their boundaries. However, when proof of strength is shown by dynamic tests simulating actual load conditions, the 3-second limit does not apply. Ultimate loads are limit loads multiplied by the appropriate prototype ultimate factor of safety specified in NASA-STD-5001. For structural elements containing beryllium or beryllium alloys, the prototype ultimate factor of safety is 1.6.

3.2.9.5 Structural Stiffness

ABIPOR D364 Stiffness of the ABI structures and their attachments **shall** be designed by consideration of their performance requirements and their handling, transportation and launch environments.

ABIPOR D365 Special stowage provisions **shall** be used if required to prevent excessive dynamic amplification during handling, transportation and transient flight events.

3.2.9.6 Unit Stiffness

ABIPOR D367 The fundamental resonant frequency of each ABI unit **shall** be 50 Hz (TBR) or greater when the flight unit is rigidly constrained at its spacecraft interface.

3.2.9.7 Material Properties

ABIPORD369 Material properties **shall** be based on sufficient tests of the material meeting approved specifications to establish design values on a statistical basis.

ABIPORD370 Design values **shall** account for the probability of structural failures and loss of any required function due to material variability.

3.2.9.8 Critical Members Design Values

ABIPORD374 For critical members, design values **shall** be selected to assure strength with a minimum of 99 percent probability and 95 percent confidence. Structural members are classified as critical when their failure would result in loss of structural integrity of the flight units.

3.2.9.9 Redundant Members Design Values

ABIPORD376 For redundant members, design values **shall** be selected to assure strength with a minimum of 90 percent probability and 95 percent confidence. Structural members are classified as redundant when their failure would result in the redistribution of applied loads to other structural members without loss of structural integrity.

3.2.9.10 Selective Design Values

ABIPORD378 As an exception to ABIPORD374 and ABIPORD376, greater design values may be used if a representative portion of the material used in the structural member is tested before use to determine that the actual strength properties of that particular structural member will equal or exceed those used in the design.

3.2.9.11 Structural Reliability

ABIPORD380 The strength, detailed design, and fabrication of the structure **shall** prevent any critical failure due to fatigue, corrosion, manufacturing defects and fracture throughout the life of the ABI resulting in the loss of any mission objective.

ABIPORD381 Accounting for the presence of stress concentrations and the growth of undetectable flaws, the ABI structures **shall** withstand loads equivalent to four complete service lifetimes.

ABIPORD382 While subjected to any flight operational load up to limit flight operational loads, the resulting deformation of the residual ABI structures **shall** not interfere with the operation of the ABI units.

ABIPORD383 After any load up to limit loads, the resulting permanent deformation of the residual instrument flight unit structures **shall** not interfere with the operation of the ABI units.

3.2.9.12 Mechanisms

Deployment, sensor, pointing, drive, separation mechanisms and other moving mechanical assemblies may be designed using MIL-A-83577B and NASA TP-1999-206988.

ABIPORD389 All ABI mechanisms **shall** meet performance requirements while operating in an earth gravity environment with any orientation of the gravity vector (TBR).

ABIPORD390 Moving mechanical assemblies **shall** have torque and force ratios per section 2.4.5.3 of GEV-SE using a NASA approved classification of each spacecraft mechanism

ABIPORD391 For all operating points of the actuators, all rotational actuators **shall** have available a continuous maximum torque output greater than 7.0 milli-Newton meters.

ABIPORD392	For all operating points of the actuators, all linear actuators **shall** have available a continuous maximum force output greater than 0.28 N.
ABIPORD393	For ABI mechanisms using closed-loop control, gain and phase margins **shall** be greater than 12 dB, and greater than 40 degrees, respectively including the effects of the dynamic properties of any flexible structure.
ABIPORD394	All ABI mechanisms requiring restraint during launch **shall** be caged during launch without requiring power to maintain the caged condition.
ABIPORD395	All ABI mechanisms requiring restraint **shall** be released from a caged condition by command.
ABIPORD396	All ABI mechanisms requiring restraint **shall** be returned to a caged condition ready for launch by either command or by manual actuation of an accessible caging device.

3.2.9.13 Pressurized Units

ABIPORD400	ABI pressurized systems **shall** follow the requirements in accordance with EWR-127-1 and MIL-STD-1522A for the design of pressurized systems.
ABIPORD401	The ABI **shall** have no open fluid reservoirs when delivered to the spacecraft contractor.

3.2.10 Thermal Requirements

3.2.10.1 Temperature Limits

ABIPORD403	The ABI contractor **shall** establish Mission Allowable Temperatures (MAT) for the ABI with at least 5^{O} K of analytical/test uncertainty. Thermal margin is defined as the temperature delta between MAT versus the bounding predictions plus analytical uncertainty.
ABIPORD404	The ABI **shall** maintain thermally independent units and their internal components within MAT limits during all flight operational conditions including bounding worst-case environments.

3.2.10.2 Outgassing Temperature

ABIPORD406	The ABI **shall** maintain the thermally independent units and their internal components within Out-gassing Allowable Temperatures (OAT) during all out-gassing procedures

3.2.10.3 Non Operational Temperature

ABIPORD408	The Non-Operational Temperatures (NOT) range **shall** extend at least 20^{O} K warmer than the hot MAT and at least 20^{O} K colder than the cold MAT.
ABIPORD409	The cold NOT **shall** be -25^{O} C or colder.

3.2.10.4 Thermal Control Hardware

ABIPORD411	There **shall** be two or more serial and independent controls for disabling any heater where any failed on condition would cause over-temperature conditions or exceed the instrument power budget.
ABIPORD412	The ABI heaters **shall** be sized to have 25% margin for worst case conditions.
ABIPORD413	When the instrument is off, instrument survival heaters **shall** maintain independent unit temperatures above non-operational limits.

ABIPORD414 The ABI survival heaters **shall** be thermostatically controlled.

3.2.10.5 Detector Cooling Margin

ABIPORD330 The following operating thermal margins **shall** be maintained in detector cooling margin:
50% up to and including the conceptual design phase,
45% up to and including Preliminary Design Review (PDR),
40% up to and including Critical Design Review (CDR), and
30% thereafter including test and launch.
The detector operating thermal margin is based on heat loads. Detector operating thermal margin is the excess system cooling capability divided by the heat load (including End of Life (EOL) dissipations, parasitics and external fluxes). For multistage cooling systems, the margins apply to all stages simultaneously.

3.2.10.6 Multi-Layer Insulation

ABIPORD416 Multi-Layer Insulation (MLI) **shall** have provisions for venting and electrical grounding to prevent Electro-Static Discharge (ESD).

3.2.11 Onboard Processors Requirements

3.2.11.1 Flight Load Non-Volatile Memory

ABIPORD418 The entire flight software image **shall** be contained in non-volatile memory at launch.

3.2.11.2 Commandable Reinitialization

ABIPORD420 The On-board Processor **shall** provide for reset by command of software.

3.2.11.3 Deterministic Power-on Configuration

ABIPORD424 The On-Board Processor **shall** initialize upon power-up into a predetermined configuration.

3.2.11.4 Fail-safe Recovery Mode

ABIPORD422 The Instrument **shall** provide a fail-safe recovery mode dependent on a minimal hardware configuration capable of accepting and processing a minimal command subset sufficient to load and dump memory.

ABIPORD425 In fail-safe recovery mode the instrument **shall** be commandable to begin execution at a specified memory address.

3.2.12 Flight Software Requirements

3.2.12.1 Language and Methodology

ABIPORD427 All software developed for the ABI instrument **shall** be developed with ANSI/ISO standard languages and a widely-accepted, industry-standard, formal software design methodology. Minimal use of processor-specific assembly language is permitted for certain low-level programs such as interrupt service routines and device drivers with NASA approval.

3.2.12.2 Software Module Upload

ABIPORD429 The flight software **shall** be reprogrammable on-orbit without computer restart.

ABIPORD430 The flight software **shall** be capable of being uploaded in modules, units, segments, and objects which **shall** be usable immediately after completion of an upload of the modified modules, units, segments, and objects.

ABIPORD431 Activation of the modified modules, units, segments, and objects **shall** not require completion of an upload of the entire flight software image.

3.2.12.3 Flexibility and Ease of Software Modification

ABIPORD433 The ABI flight software design **shall** be flexible and table-driven.

ABIPORD434 The ABI flight software scheduling and prioritization **shall** have rigid schedules to ensure timely completion.

ABIPORD435 All software data that are modifiable and examinable by ground operators **shall** be organized into tables that can be referenced by table number so table data can be loaded and dumped by the ground without reference to memory address.

ABIPORD436 The definition of instrument commands within the ground database **shall** not be dependent on physical memory addresses within the flight software.

3.2.12.4 Version Identifiers

ABIPORD438 All software and firmware versions **shall** be implemented with an internal identifier (embedded in the executive program) that can be included in the instrument engineering data.

ABIPORD439 This software identifier **shall** be keyed to the configuration management process.

3.2.12.5 Flight Processor Resource Sizing

ABIPORD8441 During development, flight processors providing computing resources for instrument subsystems **shall** be sized for worst case utilization not to exceed the capacity shown below (measured as a percentage of total available resource capacity):

Flight Processor Resource Utilization Limits

	S/W PDR	S/W CDR	S/W AR
RAM Memory	40%	50%	60%
ROM Memory	50%	60%	70%
CPU	40%	50%	60%

3.2.12.6 Software Event Logging

ABIPORD443 The flight software **shall** include time-tagged event logging in telemetry.

ABIPOR The event messages **shall** capture all anomalous events, redundancy management switching of

D444	instrument components, mode transitions, and important system performance events.
ABIPORD445	All flight software components **shall** utilize a common format for event messages.
ABIPORD446	The flight software **shall** provide a means for command to enable and disable queuing of individual event messages.
ABIPORD447	The flight software **shall** buffer a minimum of 1000 event messages while the event messages are queued for telemetering to the ground.
ABIPORD448	The event message queue **shall** be configurable by command to either (a) discard the new events, or (b) overwrite oldest events when the queue is full.
ABIPORD449	The flight software **shall** maintain counters for: a) the total number of event messages generated b) the number of event messages discarded because of queue overflow c) the number of event messages not queued due to being disabled

3.2.12.7 Warm Restart

ABIPORD451	The flight software **shall** provide a restart by command with preservation of the event message queue and memory tables.

3.2.12.8 Memory Tests

ABIPORD453	The flight software **shall** provide a mechanism to verify the contents of all memory areas.

3.2.12.9 Memory Dump

ABIPORD455	The flight software, and associated on-board computer hardware, **shall** provide the capability to dump any location and any size of on-board memory to the ground upon command.
ABIPORD456	The flight software memory dump capability **shall** not disturb normal operations and instrument data processing.

3.2.12.10 Telemetry

ABIPORD458	Telemetry points sampled by the instrument **shall** be controlled by an on-orbit modifiable table.
ABIPORD459	The sample rate of every instrument telemetry point **shall** be controlled by an on-orbit modifiable table.

3.2.13 Power Requirements

3.2.13.1 Power Regulators and Supplies

ABIPORD487	The ABI power regulators and supplies **shall** have a phase margin of greater than 45 degrees.
ABIPORD488	The ABI power regulators supplies across the spacecraft **shall** have a gain margin of greater than 12 dB.

3.2.13.2 Fuses

ABIPOR	The ABI **shall** not contain fuses.

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3.2.14 Magnetic Properties

ABIPORD492 The change in the magnetic field produced by the ABI sensor, electronics, or power supply modules **shall** be less than 30 nanoTesla peak-to-peak for any operating mode, up to a single low pass bandwidth of 1.0 Hz, in any axis when measured at a distance of 1 meter from any face of a module.

3.2.15 Spacecraft Level Ground Testing

ABIPORD495 The ABI shall accommodate operational testing in all modes and states for indefinite periods during Spacecraft level Thermal Vacuum in at least the following two orientations:
1) Spacecraft +Y axis in the nadir direction
2) Spacecraft -X axis in the nadir direction.

4 Appendix A Upwelling Radiance Data Sets

ABIPORD497 TBS

5 Acronyms

A/D	Analog-to-Digital
ABI	Advanced Baseline Imager
ABI-GS	ABI-Ground System
ACS	Attitude Control System
CDR	Critical Design Review
CONUS	Continental United States (excluding Alaska and Hawaii)
EOL	End of Life
ESD	Electro-Static Discharge
FOR	Field of Regard
GIRD	General Interface Requirements Document
GOES	Geostationary Operational Environmental Satellite
INR	Image Navigation and Registration
IR	Infrared
K	Kelvin
kHz	Kilohertz
km	Kilometers
m	meters
MAT	Mission Allowable Temperature
Mbps	Mega-bits-per-second
MLI	Multi-Layer Insulation
MMD	Mean Mission Duration
MTF	Modulation Transfer Function
mW	Milliwatt
NASA	National Aeronautics and Space Administration
NEDN	Noise Equivalent Delta Radiance
NEDT	Noise Equivalent Delta Temperature

NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOT	Non-Operational Allowable Temperature
OAT	Outgassing Allowable Temperature
PDR	Preliminary Design Review
PORD	Performance Operational Requirements Document
rad	Radian
RMS	Root Mean Square
SNR	Signal-to-Noise Ration
sr	Steradian
S/W	Software
TBR	To Be Reviewed
TBS	To Be Supplied
TDI	Time Delay and Integration
Tmin	Minimum Scene Temperature
Tmax	Maximum Scene Temperature
UIID	Unique Instrument Interface Document
um	Micrometers (Microns)
urad	Microradian